

1 We claim:

1. A catheter for emitting x-ray radiation comprising:
a flexible catheter shaft having a distal end;
an x-ray unit coupled to the distal end, wherein
5 the x-ray unit comprises an anode, a cathode and an insulator,
wherein the anode and cathode are coupled to the insulator to
define a vacuum chamber.

2. The catheter of claim 1, wherein the cathode is a
field emission cathode.

10 3. The catheter of claim 1, wherein the catheter shaft
comprises a coaxial cable.

4. The catheter of claim 1, wherein the insulator is
chosen from the group consisting of beryllium oxide, aluminum
oxide, or pyrolytic boron nitride.

15 5. The catheter of claim 1, wherein the cathode and
the anode are coupled to a voltage generator.

6. The catheter of claim 1, further comprising a guide
wire lumen.

7. The catheter of claim 6, wherein the guide wire
20 lumen extends partially through the catheter shaft.

8. The catheter of claim 6, wherein the guide wire
lumen extends partially through the x-ray unit.

9. The catheter of claim 1, further comprising a means
for centering the x-ray unit within a lumen.

25 10. The catheter of claim 1, wherein the cathode is a
ferroelectric material.

- 1 11. An x-ray catheter comprising:
- a flexible catheter shaft for being advanced
through lumens of the vascular system, the catheter shaft having
a distal end;
- 5 an x-ray unit coupled to the distal end, the x-ray
unit comprising an anode, a cathode and an insulator, wherein the
anode and cathode are coupled to the insulator to define a vacuum
chamber.
12. The catheter of claim 11, wherein the insulator
10 comprises pyrolytic boron nitride.
13. The catheter of claim 11, wherein the anode
comprises tungsten or platinum and the cathode comprises
graphite.
14. The catheter of claim 11, wherein the cathode is a
15 field emission cathode.
15. The catheter of claim 12, wherein the cathode and
anode are coupled to a voltage generator.
16. The catheter of claim 15, wherein the catheter
shaft comprises a coaxial cable coupling the anode and cathode to
20 the voltage generator.
17. The catheter of claim 16, further comprising means
for centering the x-ray unit within a lumen.
18. A catheter for the emission of x-ray radiation
comprising:
- 25 a flexible catheter shaft having a distal end;
 an x-ray generating unit coupled to the distal
end, the x-ray generating unit comprising an anode, a cathode and

1 an insulator, wherein the anode and cathode are coupled to the
insulator to define a vacuum chamber, and

wherein the x-ray generating unit has a diameter
less than about 4 mm.

5 19. The catheter of claim 18, wherein the x-ray
generating unit has a diameter of about 1 mm.

20. The catheter of claim 19, wherein the x-ray
generating unit has a length of about 7 mm.

21. The catheter of claim 18, wherein the x-ray
10 generating unit has a length less than about 15 mm.

22. The catheter of claim 18, wherein the insulator
comprises pyrolytic boron nitride.

23. An x-ray catheter for use in irradiating the wall
of a lumen comprising:

15 a flexible catheter shaft having a distal end;
an x-ray generating unit; and
means for centering the x-ray generating unit
within the lumen.

24. A method for preventing restenosis of a lumen
20 comprising:

(a) advancing an x-ray catheter through a lumen
to a first location adjacent an intended site of the lumen,
wherein the x-ray catheter comprises a flexible catheter shaft
with a distal end and an x-ray generating unit coupled to the
25 distal end, the x-ray generating unit comprising an anode, a
cathode and an insulator, wherein the anode and cathode are
coupled to the insulator to define a vacuum chamber;

1 (b) causing the emission of an effective dose of
x-ray radiation to prevent restenosis; and

(c) removing the catheter.

25. The method of claim 24, wherein step (b) comprises
5 causing the emission of radiation within a particular energy
range to achieve a particular depth of penetration.

26. The method of claim 24, wherein the causing step
(b) further comprises applying a predetermined voltage between
the anode and the cathode to achieve the particular depth
10 penetration.

27. The method of claim 24, further comprising
irradiating tissue at a rate of about 1-50 grays per minute.

28. The method of claim 27, wherein the irradiating
step is conducted for about 1 minute.

15 29. The method of claim 24, wherein step (b) comprises
causing the emission of x-rays having an energy of about 8-10
KeV.

30. The method of claim 24, further comprising
centering the x-ray unit within the lumen prior to the step (b).

20 31. The method of claim 24, wherein the advancing step
comprises advancing the x-ray catheter through a lumen of the
vascular system through an exchange tube.

32. The method of claim 24, wherein the advancing step
comprises advancing the x-ray catheter through a lumen of the
25 vascular system over a guide wire and through a guide catheter.

33. The method of claim 32, wherein a portion of the
x-ray catheter is advanced over the guide wire.

1 34. The method of claim 24, further comprising
positioning the x-ray unit at a second location and causing the
emission of x-ray radiation at the second location.

5 35. The method of claim 24, further comprising
positioning the x-ray unit at a plurality of locations and
causing the emission of x-ray radiation at each of the plurality
of locations.

10 36. The method of claim 24, further comprising
conducting an angioplasty procedure prior to step (a), wherein
the intended site of step (a) is the site of the angioplasty
procedure.

37. A method for providing x-ray radiation treatment
comprising:

15 advancing an x-ray catheter through a lumen to an
intended site, wherein the x-ray unit comprises a flexible
catheter shaft with a distal end and an x-ray generating unit
coupled to the distal end, the x-ray generating unit comprising
an anode, a cathode and an insulator, wherein the anode and
cathode are coupled to the insulator to define a vacuum chamber;

20 causing the emission of an effective dose of x-ray
radiation; and

removing the catheter.

38. The catheter of claim 2, wherein the cathode is
chosen from the group consisting of graphite, titanium carbide,
25 carbides, metals, and graphite coated with titanium carbide.

39. The catheter of claim 1, further comprising a
guide wire lumen extending through the catheter shaft.

1 40. The catheter of claim 2, wherein the cathode
comprises silicon and the x-ray unit further comprises a grid
proximate the cathode.

 41. The catheter of claim 2, wherein the cathode
5 comprises silicon needles.

 42. The catheter of claim 11, wherein the x-ray unit
irradiates tissue at a rate of at least about 1 gray per minute.

 43. The catheter of claim 1, wherein the anode is
coupled to a wall of the insulator, wherein the wall is tapered
10 towards the anode.

 44. The catheter of claim 3, wherein:

 the coaxial cable comprises an outer conductor and a
central conductor;

 the insulator has a tubular portion with proximal and
15 distal ends, the coaxial cable being coupled to the proximal end,
the anode being coupled to the proximal end and to the central
conductor of the coaxial cable, and the cathode being coupled to
the distal end;

 the catheter further comprises a conductive surface
20 surrounding the tubular insulator, coupling the cathode to the
outer conductor of the coaxial cable; and

 the insulator and cathode define an annular region
proximate the coupling between the cathode and the insulator, the
annular region being screened from an electrical field generated
25 between the anode and the cathode by the conductive surface and a
portion of the cathode.

1 45. The catheter of claim 44, wherein the insulator
comprises a wall depending from the proximal end of the tubular
portion, the wall being angled toward the anode and the vacuum
chamber.

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